Appendix G

Evaluation of Varian CLINACs

WRAMC CLINAC Surveys

On Dec. 27, 2011, various Gamma Spectra, Gamma Scans and Alpha/Beta measurements were collected for the investigation of potential activation products on two Varian CLINAC linear accelerators and in a vacated room which contained a similar accelerator. The units and empty room were located in Building 2, first floor, radiology/oncology area. Room 1H25 contained a Varian Model 600C operating at 6 MV photon, Room 1H27 contained a Varian Model 2100C operating at 6 MV photon, and Room 1H33 previously contained a Varian Model 2100ix operating at 15 MV photon (20 MeV electrons).

Gamma spectra and Gamma scans were collected on the exterior of the plastic housing of the CLINACs utilizing RSA Laboratories URSA II Multi-Channel Analyzers with a Ludlum Model 44-10 2X2 NaI detector and an Alpha Spectra Model 20Dt063Qb2 FIDLER detector. Energy calibrations were performed on each detector using ^{230}Th and ^{137}Cs sources prior to spectra collection.

Alpha/Beta measurements were collected utilizing a Ludlum model 2360 data logger coupled to a Ludlum model 43-68 gas flow proportional detector. Daily quality control checks were performed for response to radiation with ^{14}C for low energy Beta, ^{99}Tc for high energy beta and ^{230}Th for Alpha. Daily background level checks were also performed.

Measurement locations on the CLINAC's were determined from cross sectional diagrams depicting the beam pathway (see Figure 1.), process knowledge and scanning. Static location 1 was established on the right side of the unit (facing the unit) at the head mounting flange. Static location 2 was established at the front of the unit (facing the unit) centerline to the beam guide. Spectra were collected at static location 1. Alpha/Beta measurements were taken at both locations on the exterior of the plastic housing.

The spectra were analyzed in qualitative form to identify any listed radionuclide of concern or potential activation products and also against background spectra in a comparative analysis. Comparative analysis of NaI 2X2 spectra verses FIDLER spectra within like kind energy ranges was also performed. No peaks were identified in any of the spectra. Minor differences in the contour of the spectra can be seen in figures 1 through 13, these variations are likely attributable to the material in which the spectra was collected and are inconclusive in the identification of any radioactive materials.

Gamma scans for low energy were collected using the FIDLER detector. Gamma scans for high energy were collected using the NaI 2X2. All survey data was collected and stored on a handheld computer for further analysis. Surveys were conducted on 100% of the room surfaces. A summary of these data can be found in Tables 1 and 2.

Due to the unique construction of the rooms, a like kind reference area background could not be located. The scan data was evaluated by frequency distribution plots where the X axis represents the count rate in cpm and the Y axis represents the number of occurrences. See figures 14 through 21 for visual trend analysis. The data was also evaluated by calculation of Z-scores for identification of distribution outliers.

Z-scores are calculated by comparing each data point against the mean and standard deviation of the data set as a whole.

Data was reviewed for individual data points that exceed three times the standard deviation of the set (or Z-score ≥ 3.0-sigma) calculated by:

$$Z = \frac{L_{CR} - M_{ds}}{StdDev}$$

where: Z = Z-score

L_{CR} = Location count rate , in gross cpm

M_{ds} = Mean of the data set, in gross cpm

StdDev= Standard deviation of the data set

No data point equaled or exceeded three standard deviations.

Alpha/Beta measurements were collected for two minutes and reported as net counts per minute above ambient background per detector area (126 cm^2). Beta results ranged from 440 to 541 ncpm and are above the nominal MDC of 49 cpm. Alpha measurement results could not be distinguished from background levels. These results cannot quantify nor qualify the level of radioactive material due to the area of activity being less than the active area of the detector and with a manufacturer estimated gamma efficiency of ~ 1% the source is most probably beneath the plastic head cover. Summaries of these data can be found in tables 3 through 6.

Figures

Tables

Figure 1. Varian CLINAC Cross Section

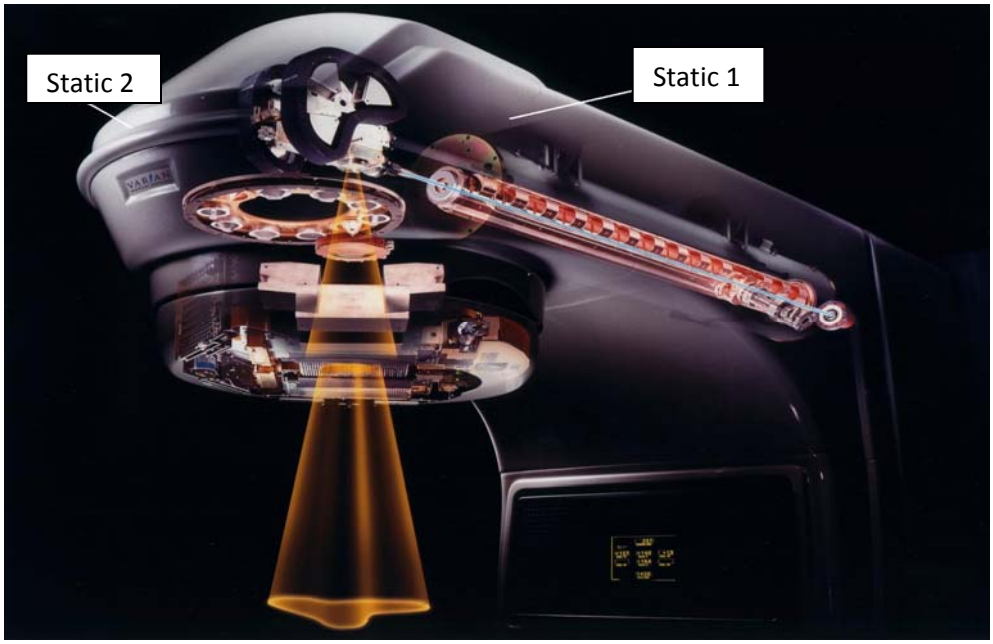

Figure 2. URSA II #200130 with FIDLER #050307AZ1 Detector Energy Calibration Spectra with Th230 12.3kev and Cs137 32.89kev peaks identified

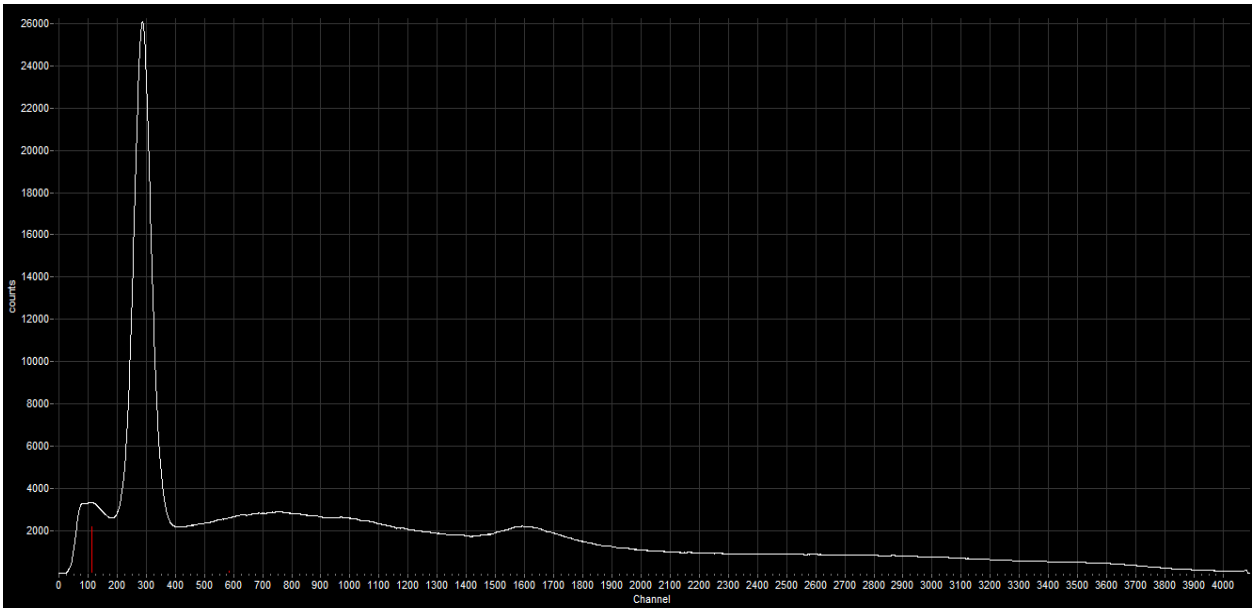

Figure 3. URSA II #200130 with FIDLER #050307AZ1 Detector Background Spectra

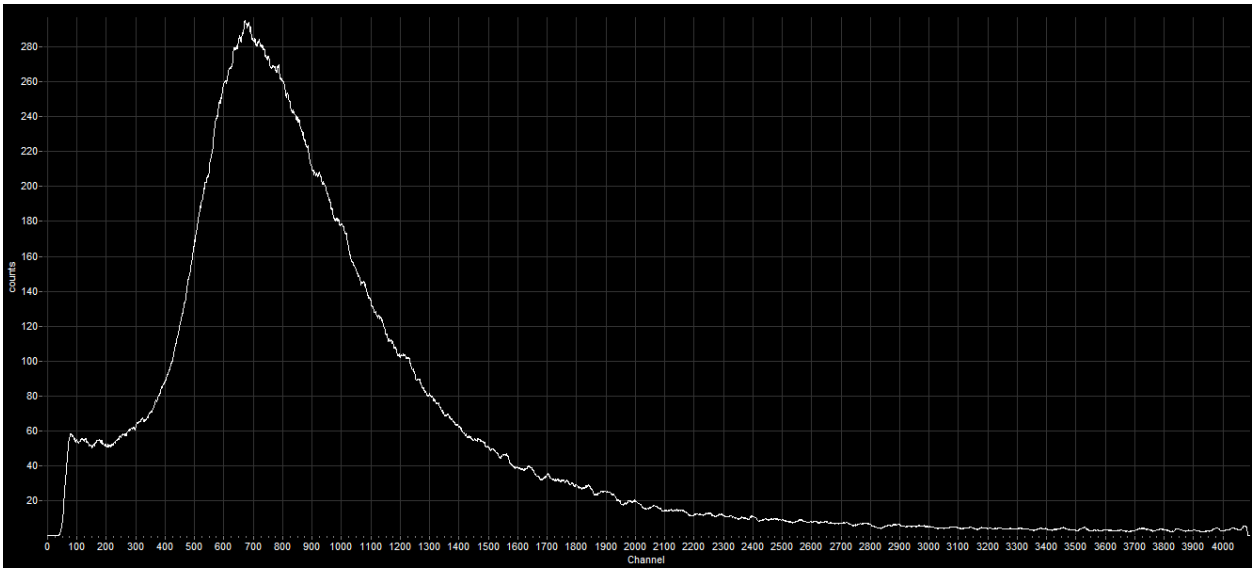

Figure 4. Building 2, Room 1H25, CLINAC Model 600C Low Energy Gamma Spectra

No identified peaks

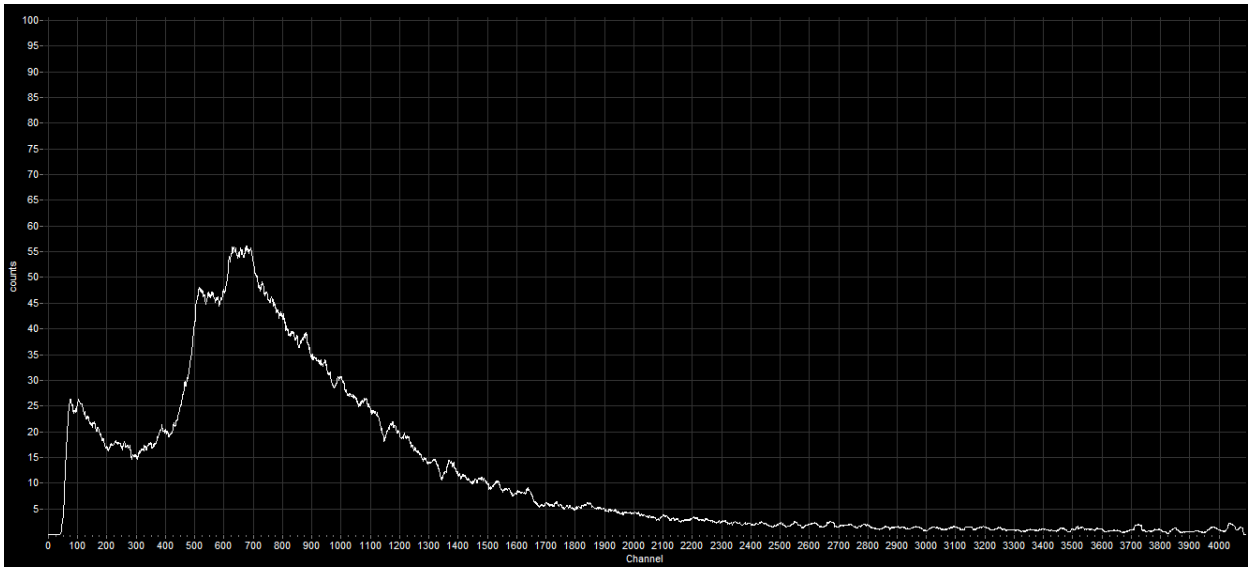

Figure 5. Building 2, Room 1H27, CLINAC Model 2100C Low Energy Gamma Spectra

No identified peaks

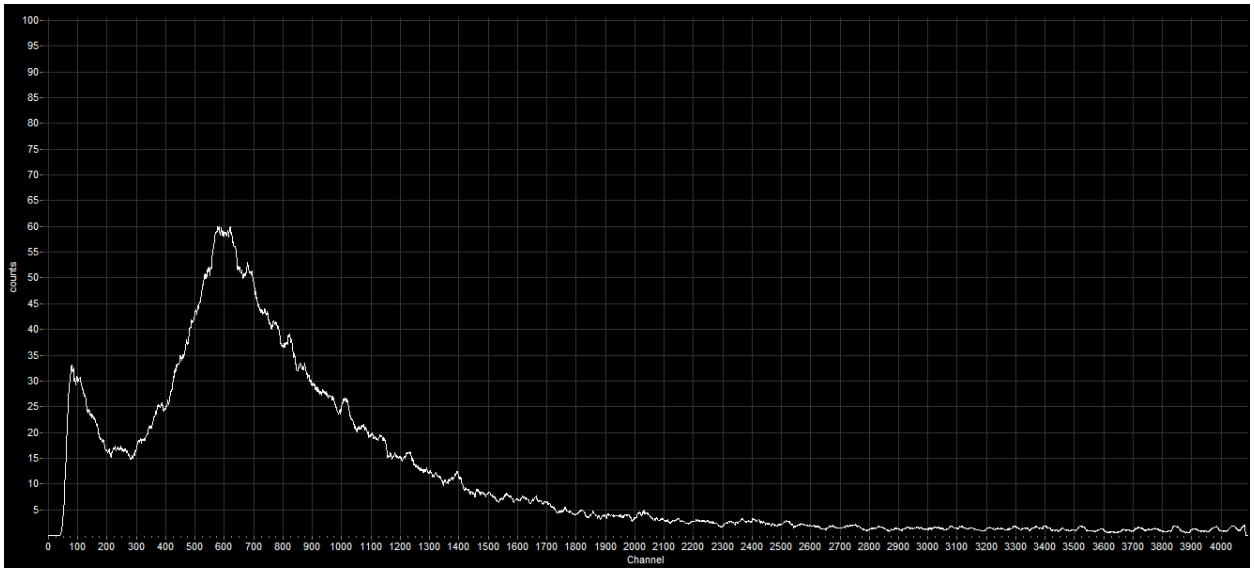

Figure 6. Building 2, Room 1H33 Floor, Low Energy Gamma Spectra

No identified peaks

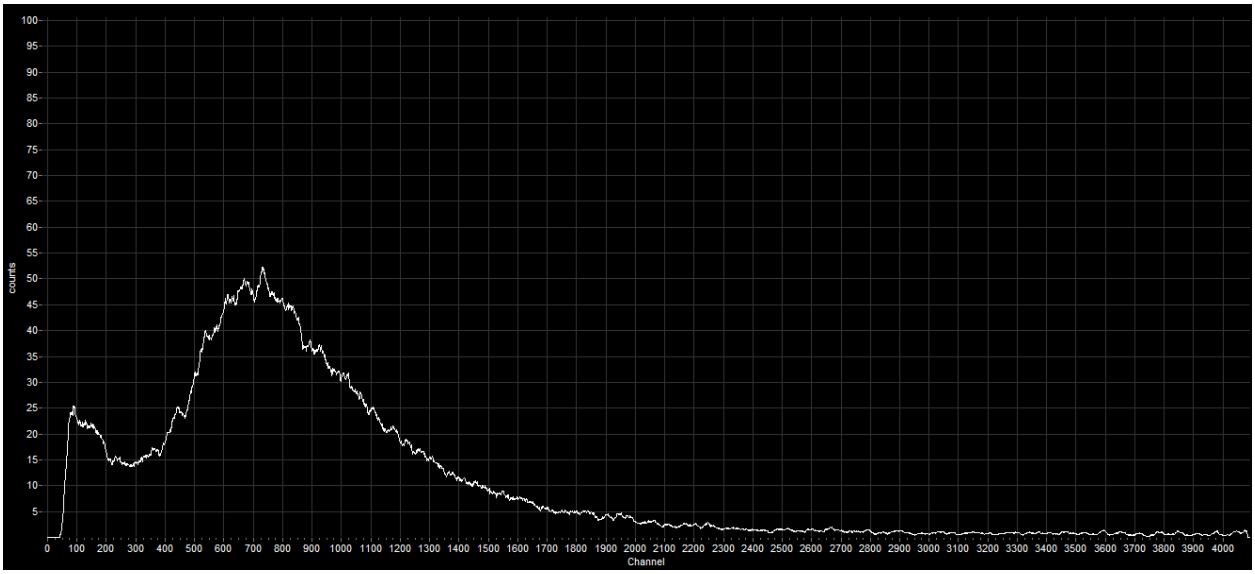

Figure 7. Building 2, Room 1H33 Ceiling, Low Energy Gamma Spectra

No identified peaks

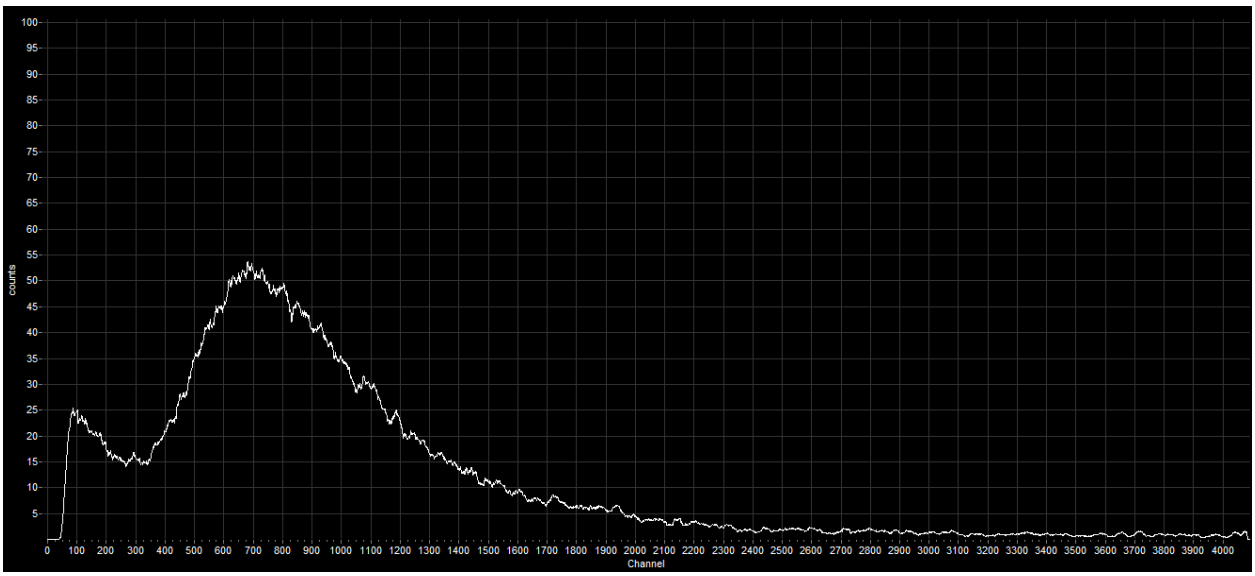

Figure 8. URSA II #200124 with NaI 2X2 #186962 Detector Energy Calibration Spectra

with Cs137 32.89kev and 662kev peaks identified

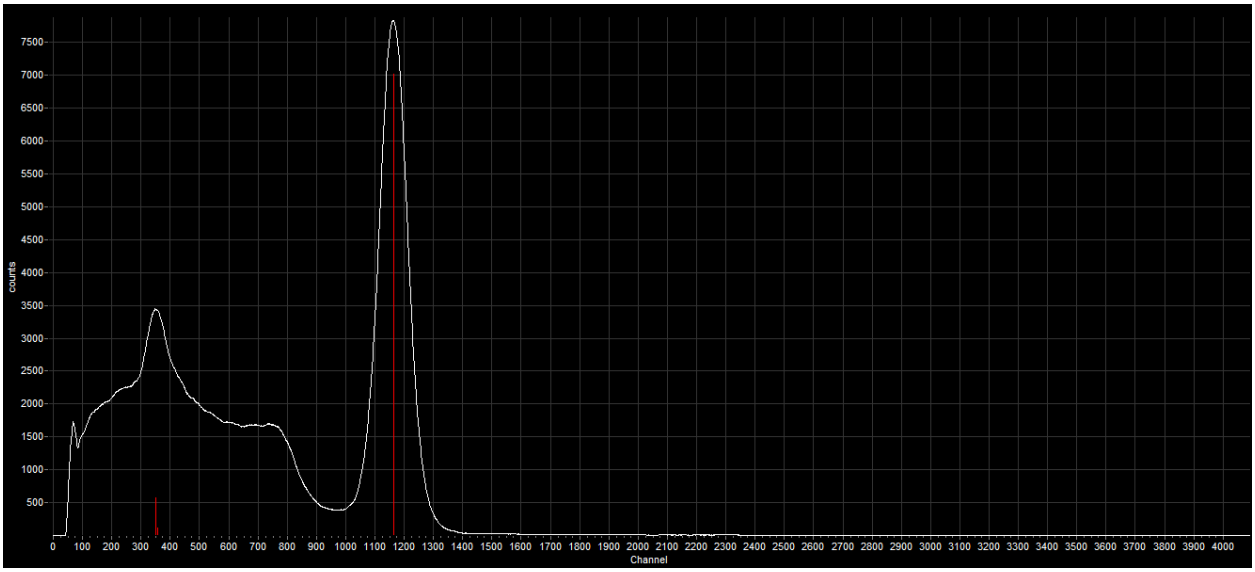

Figure 9. URSA II #200124 with NaI 2X2 #186962 Detector Background Spectra

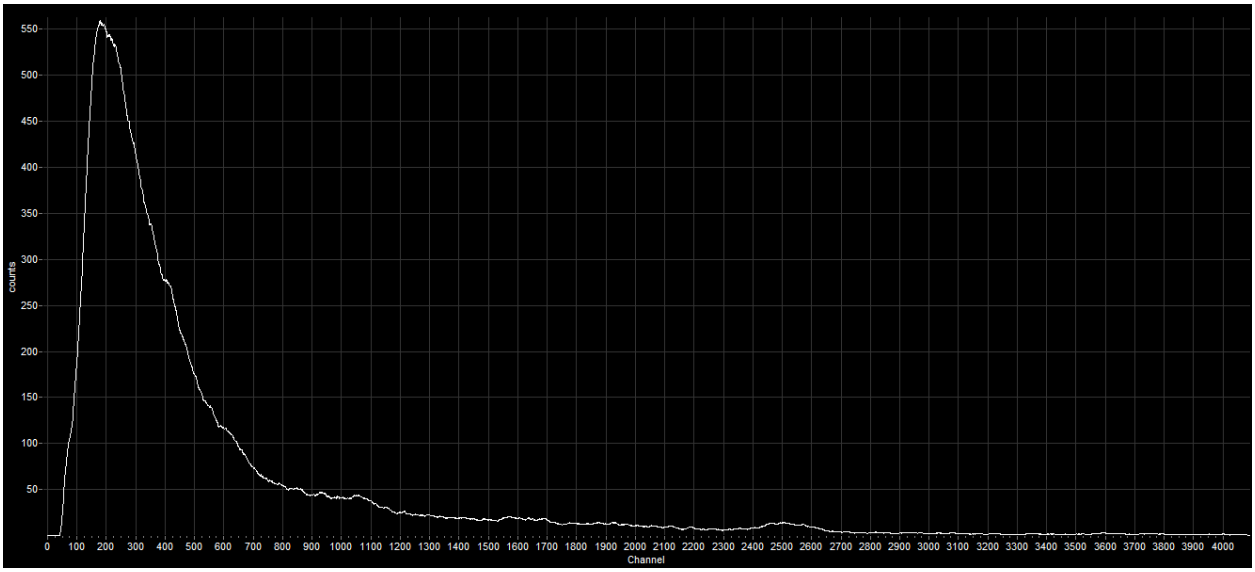

Figure 10. Building 2, Room 1H25, CLINAC Model 600C NaI 2X2 Gamma Spectra

No identified peaks

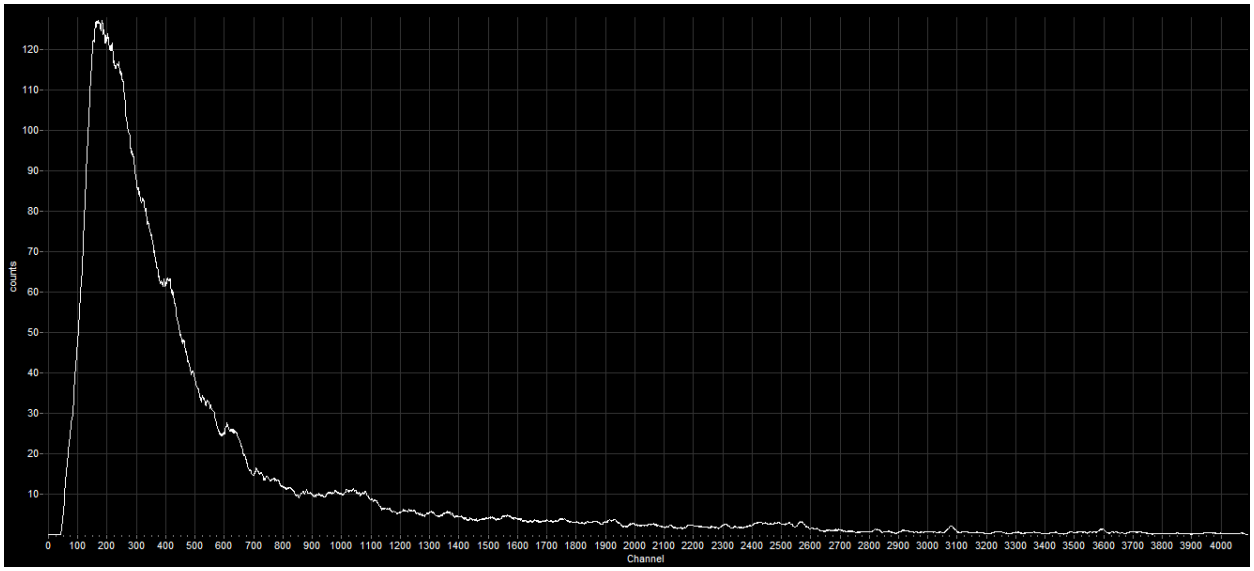

Figure 11. Building 2, Room 1H27, CLINAC Model 2100C NaI 2X2 Gamma Spectra

No identified peaks

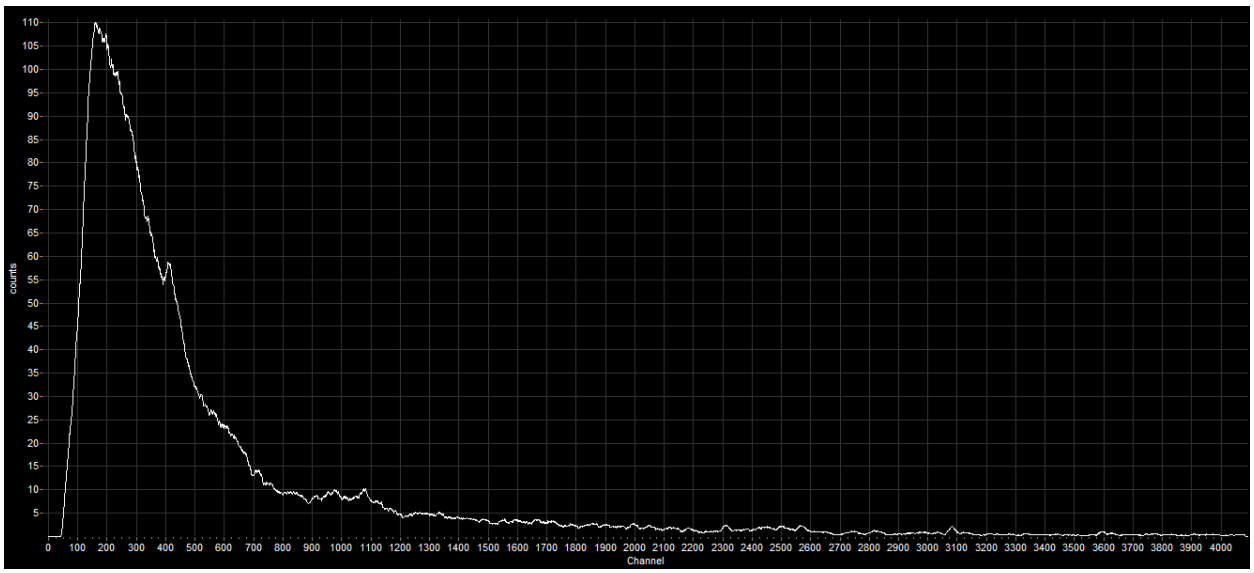

Figure 12. Building 2, Room 1H33 Floor, NaI Gamma Spectra

No identified peaks

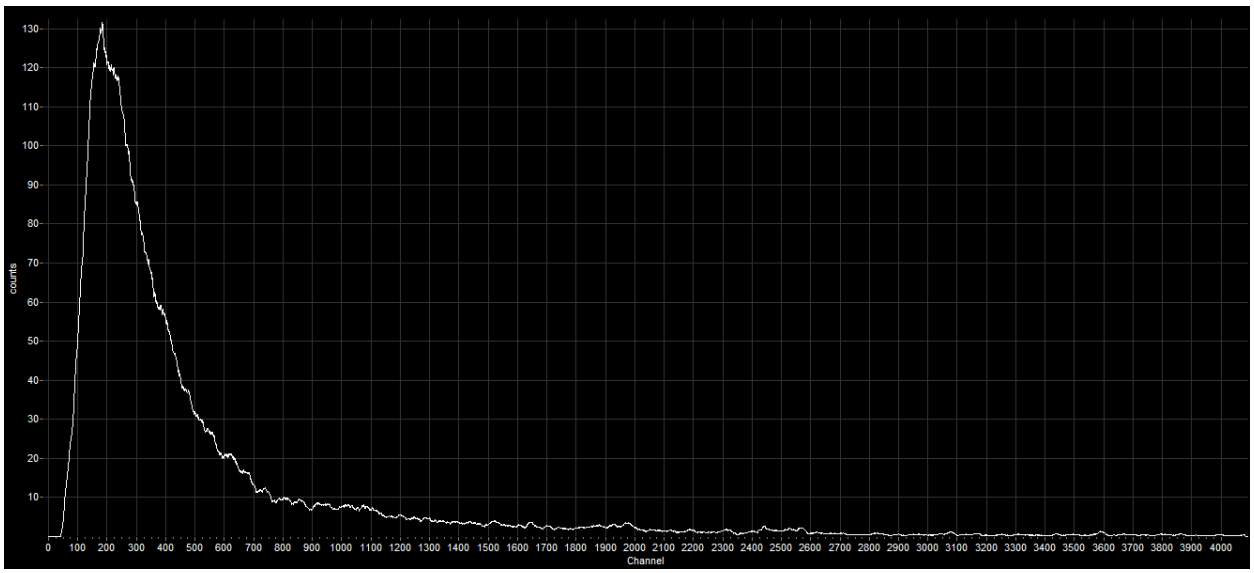

Figure 13. Building 2, Room 1H33 Ceiling, NaI 2X2 Gamma Spectra

No identified peaks

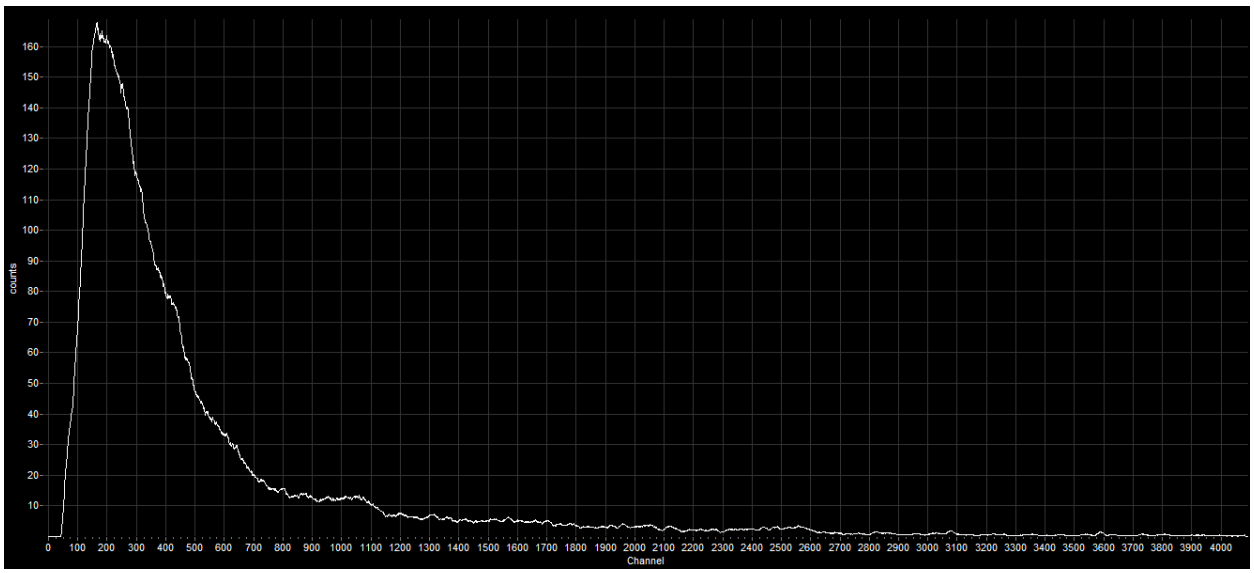

Figure 14. SU2-1H25 NaI 2X2 Data

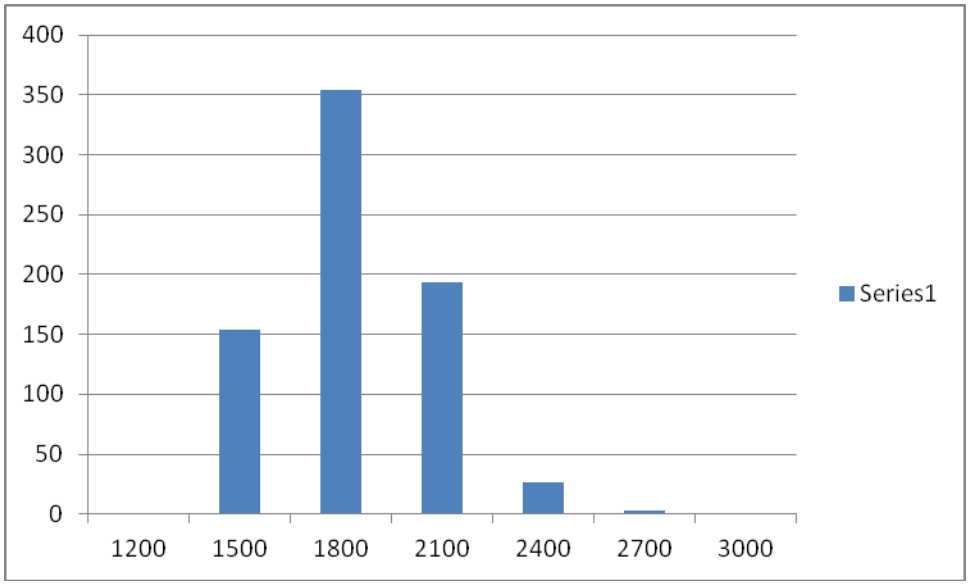

Figure 15. SU2-1H27 NaI 2X2 Data

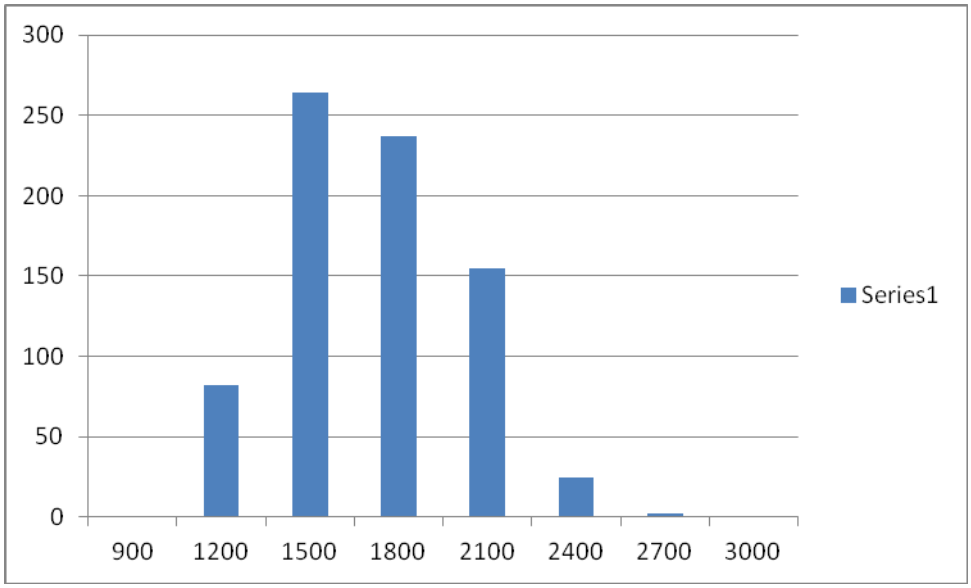

Figure 16. SU2-1H33 NaI 2X2 Data

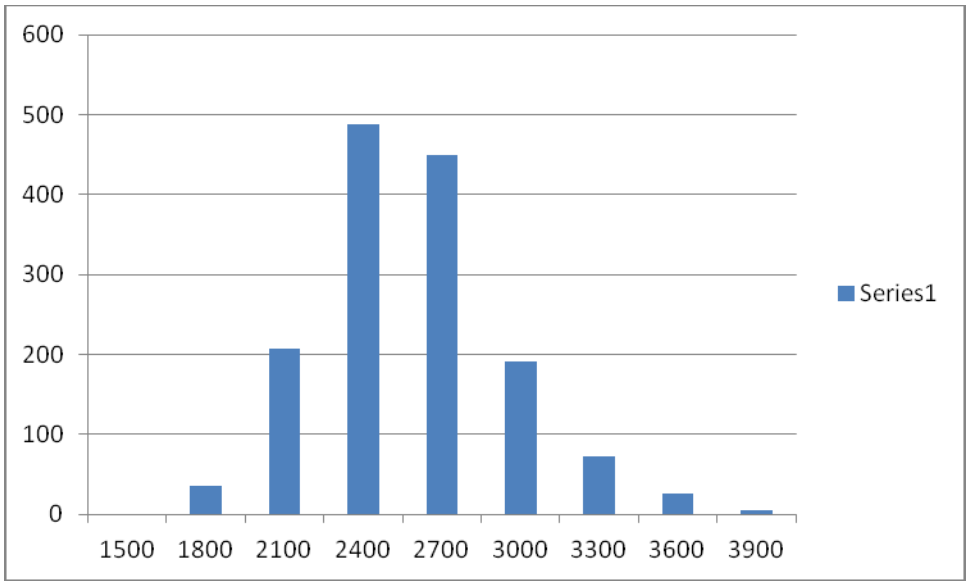

Figure 17. SU2-1H33 South Wall NaI 2X2 Data

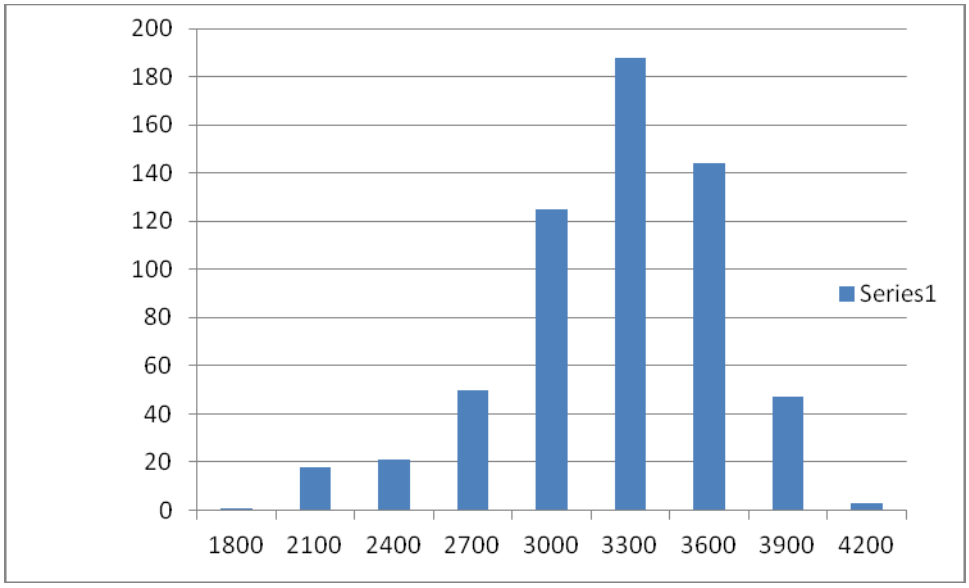

Figure 18. SU2-1H25 FIDLER Data

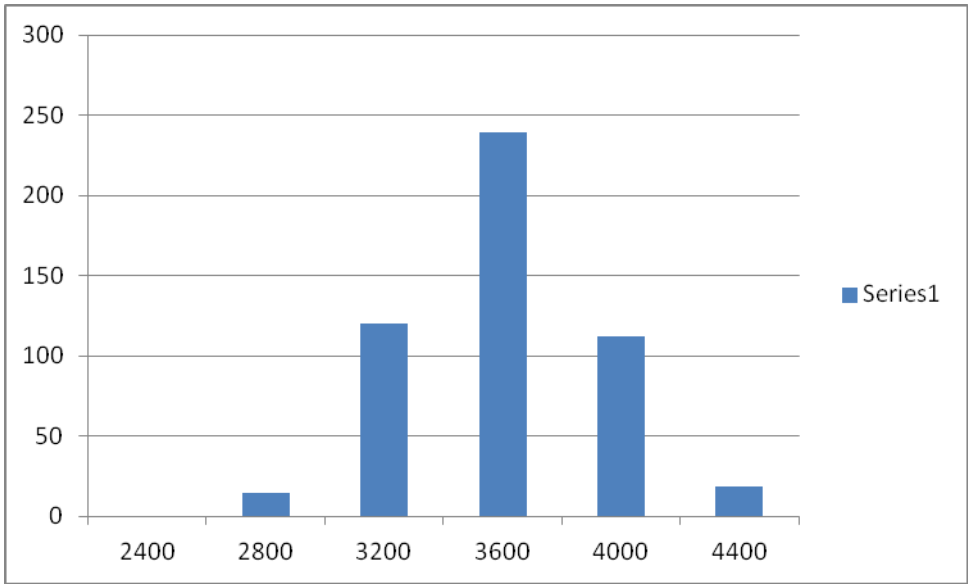

Figure 19. SU2-1H27 FIDLER Data

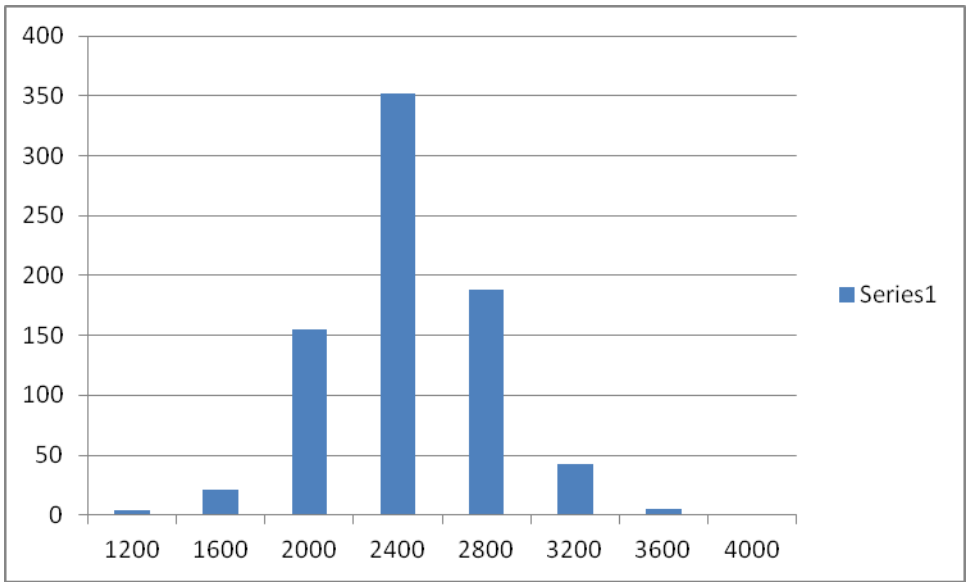

Figure 20. SU2-1H33 FIDLER Data

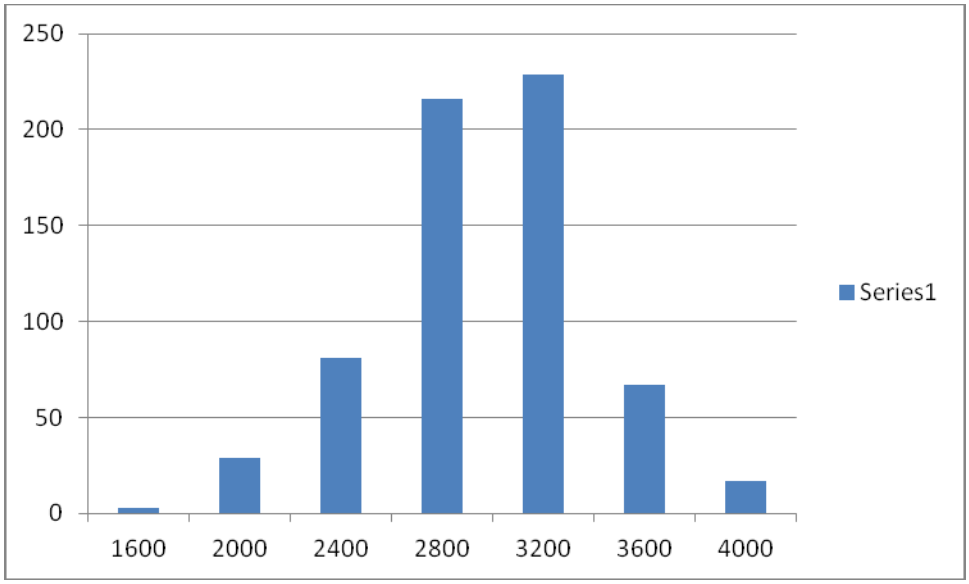

Figure 21. SU2-1H33 South Wall FIDLER Data